On the Feasibility of a User-Operated Mobile Content Distribution Network

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iCore & CommNet2 workshop on
Content Caching and Distributed Storage for Future Communication Networks
June 20, 2017, Imperial College, London
Data caps cannot keep up with demand for mobile video delivery
Facts I: CDNs focus on the fixed domain
Facts II: Mobile Video will Skyrocket

Given the massive explosion of video content available on the internet, there is a corresponding sharp increase in streamed video viewing, particularly among younger generations. Today’s teens are streaming natives, as they have no experience of a world without online video streaming.

*Ericsson Mobility Report, 2016*
Mobile Data in terms of Video

One hour of streaming per day (e.g., during commuting) consumes a 2GB data plan in less than 10 days!
Mobile micro-datacentres

All modern smartphones have at least 16GBs of memory.

16 GBs of memory translates to nearly 1,000 minutes of YouTube or 100 10-min YouTube videos.

Modern smartphone devices are always-on, always-connected, mobile data-centres for short audio/video-clips.
Working Example

• Assume:
  ✓ BBC application installed in 10M end-user devices – that’s roughly 1 in 6 devices you see around (in the UK)
  ✓ End-users split in: 1) source, 2) destination, and 3) relay nodes

• Picture this:
  ① Content Providers (CPs), say BBC, publish one new video-clip every 1 hour
  ② CPs push the video to a limited number of source nodes – source nodes have prior agreement with CPs
  ③ Source nodes exploit mobility to update destination nodes
  ④ Once updated, destination nodes can act as relay nodes for a limited amount of time.
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Result: Huge amounts of content is proactively put in users’ devices in an application-centric manner.

Challenge: Can we have every video-clip pre-loaded to the users’ devices before new content comes out (i.e., within 1h)?
ubiCDN
a distributed and ubiquitous content distribution network for data delivery at the mobile domain.

ubiCDN exploits user mobility in urban environments to proactively distribute non-real time content

Content spreads through smart, Information-Centric Connectivity
ubiCDN Components

• **Node Groups**
  – *Source nodes*: get new content pushed to their devices
  – *Destination nodes*: passively wait to receive updates
  – *Relay nodes*: act as source nodes for limited time

• **D2D Information-Aware and Application-Centric Connectivity**
  – WiFi Direct Generic Advertisement Protocol (GAS)
  – Devices advertise services/applications, e.g., *BBC-Sports-11am*

• **Incentives**
  – Source and Relay nodes are compensated
  – Compensation proportional to content distributed

• **Data Integrity/Content authentication**
  – Digital certificates from CPs
  – Digital Signatures based on Public Key Infrastructure (PKI)
  – Source and Relay nodes: Storage Delegates

ubiCDN
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Information-Aware and Application-Centric Connectivity
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Target of this study
Feasibility of a user-operated CDN

• define “Feasibility”

What percentage of population is updated within reasonable time-frames?*

F1: How many source nodes are needed?
F2: What’s the impact of relaying?
F3: What’s the impact on battery?

• Metrics:
  – **Satisfaction rate**: percentage of nodes updated within update interval
  – **Overhead**: duplicates, messages of no interest or incomplete transfers
  – **Relayed content**: percentage of messages delivered by relay nodes
  – **Energy consumption**: what percentage of battery is consumed for ubiCDN

* We define this as “update interval” and set it to 1 hour.
Evaluation: Setup and Assumptions

- ubiCDN implemented on the ONE simulator.
- Set of 10 applications, Pareto-distributed by popularity and randomly distributed among users (at least one application per user).
- We compare it with Floating Content.

**Floating Content**
- Messages stay within some area
- Messages live for some specific amount of time

*Joerg Ott et al. [www.floating-content.net](http://www.floating-content.net)
Evaluation: Setup and Assumptions

Helsinki simulation area
Evaluation: Setup and Assumptions

• Urban movement: 8.3km x 7.3km area
• Multiple movement patterns map-based defined:
  – **Source Nodes (50):**
    • 18 Buses on predefined routes.
    • 32 working day movement model with 50% evening activity
  – **Destination Nodes (1000):**
    • *Tourists (20% of destination nodes):* Random travel destinations including “points of interest” to which they travel following the shortest path, wait randomly between 2-15 minutes and then move again.
    • *Workers (80% of destination nodes):* Working day movement model: Home to work (for 7 hours) + 50% probability of evening activity, before travelling back home
Evaluation: Setup and Assumptions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Applications</td>
<td>10</td>
</tr>
<tr>
<td>Number of Source Nodes</td>
<td>50</td>
</tr>
<tr>
<td>Number of Destination Nodes</td>
<td>1000</td>
</tr>
<tr>
<td>Size of each message</td>
<td>5 MBs</td>
</tr>
<tr>
<td>App. update period</td>
<td>1 hour</td>
</tr>
<tr>
<td>D2D Link Capacity</td>
<td>31.25Mbps</td>
</tr>
<tr>
<td>Radio Range</td>
<td>60 m</td>
</tr>
</tbody>
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Feasibility 1: Number of source nodes

Flooding is more efficient, but...

5% of nodes reach out to 60% of population

Exponential increase
Feasibility 1: Number of source nodes

Less than 10% overhead – mainly due to mobility

Significant overhead – up to 50%
Feasibility 2: Impact of Relaying

Substantial gain (up to 40%) after 5-15 mins

ubiCDN gains from up to 30 mins of relaying
Feasibility 2: Impact of Relaying

- Up to 90% overhead using fltCDN
- Bounded to 20% for ubiCDN
- Space for Optimisation: Least popular applications cause little overhead
Feasibility 2: Impact of Relaying

More than 40% (ubiCDN) / 80% (fltCDN) of distribution comes from relaying
Feasibility 2: Impact of Relaying

Most nodes get updated within the first 20-25 mins
Feasibility 3: Energy – the price to pay

Energy Consumption Source nodes

<table>
<thead>
<tr>
<th>Content update size</th>
<th>ubiCDN</th>
<th>fltCDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 MB</td>
<td>~ 1%</td>
<td>~ 15%</td>
</tr>
<tr>
<td>50 MB</td>
<td>~ 1,5%</td>
<td>~ 25%</td>
</tr>
<tr>
<td>100 MB</td>
<td>~ 2%</td>
<td>~ 30%</td>
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15x less consumption

Energy Consumption Relay nodes

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</tr>
<tr>
<td>100 MB</td>
<td>100 MB</td>
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</table>
Conclusions

Data Caps cannot follow demand for mobile video
- Expected to be about 8GBs in 2020

CDNs cannot reach the mobile domain
- Can’t put a server after the BS

Pressing need for a solution to distribute heavy content in the mobile domain.

User devices as micro-data centres: **Opportunity not to be missed**

At least 50% of users updated within 30mins

Energy consumption is as low as 1% of battery capacity per hour.

Information-Centric Connectivity is necessary in this case
Key Publications
ICN Information-Resilience

“Information Resilience Through User-Assisted Caching in Disruptive Content-Centric Networks”
V. Sourlas, L. Tassiulas, I. Psaras, G. Pavlou
IFIP NETWORKING 2015
Best Paper Award

“Opportunistic Off-Path Content Discovery in Information-Centric Networks”
O. Ascigil, V. Sourlas, I. Psaras, G. Pavlou
IEEE LANMAN 2016
Best Paper Award
INRPP: In-Network Resource Pooling

I. Psaras, L. Saino, G. Pavlou
“Revisiting Resource Pooling: the Case for In-Network Resource Sharing”
ACM HotNets 2014
Modelling In-Network Caching

Centrality-Based In-Network Caching

  - Best Paper Award

  - One of top cited COMCOM papers since 2013!!
Probabilistic In-Network Caching

**ProbCache**: Probabilistic In-Network Caching

\[ \text{ProbCache}(x) = \frac{\sum_{i=1}^{c} (x-1) N_i}{T_{tw} N_x} \times \frac{x}{c} \]

Caching Capability of a Path  
Weight-based Caching

Cache-aware-/Hash-routing for ICN

Further Paper Highlights